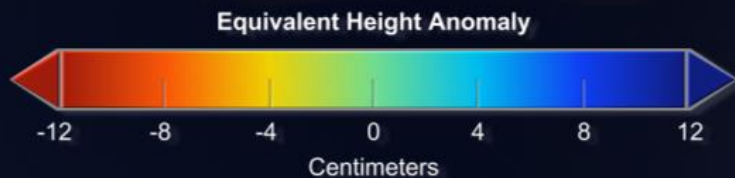


Observations of Groundwater Depletion from Space: Challenges in California and the United States

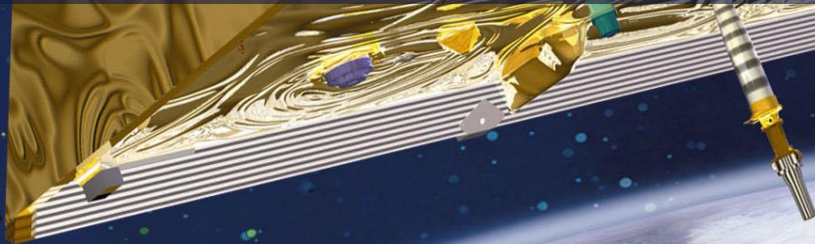
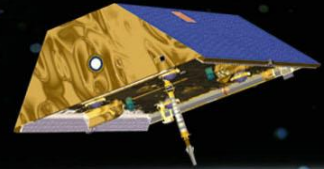
Jay Famiglietti, Professor and Director
UC Center for Hydrologic Modeling
UC Irvine

*Presentation to the
California State Water Resources Control Board
January 22, 2014*

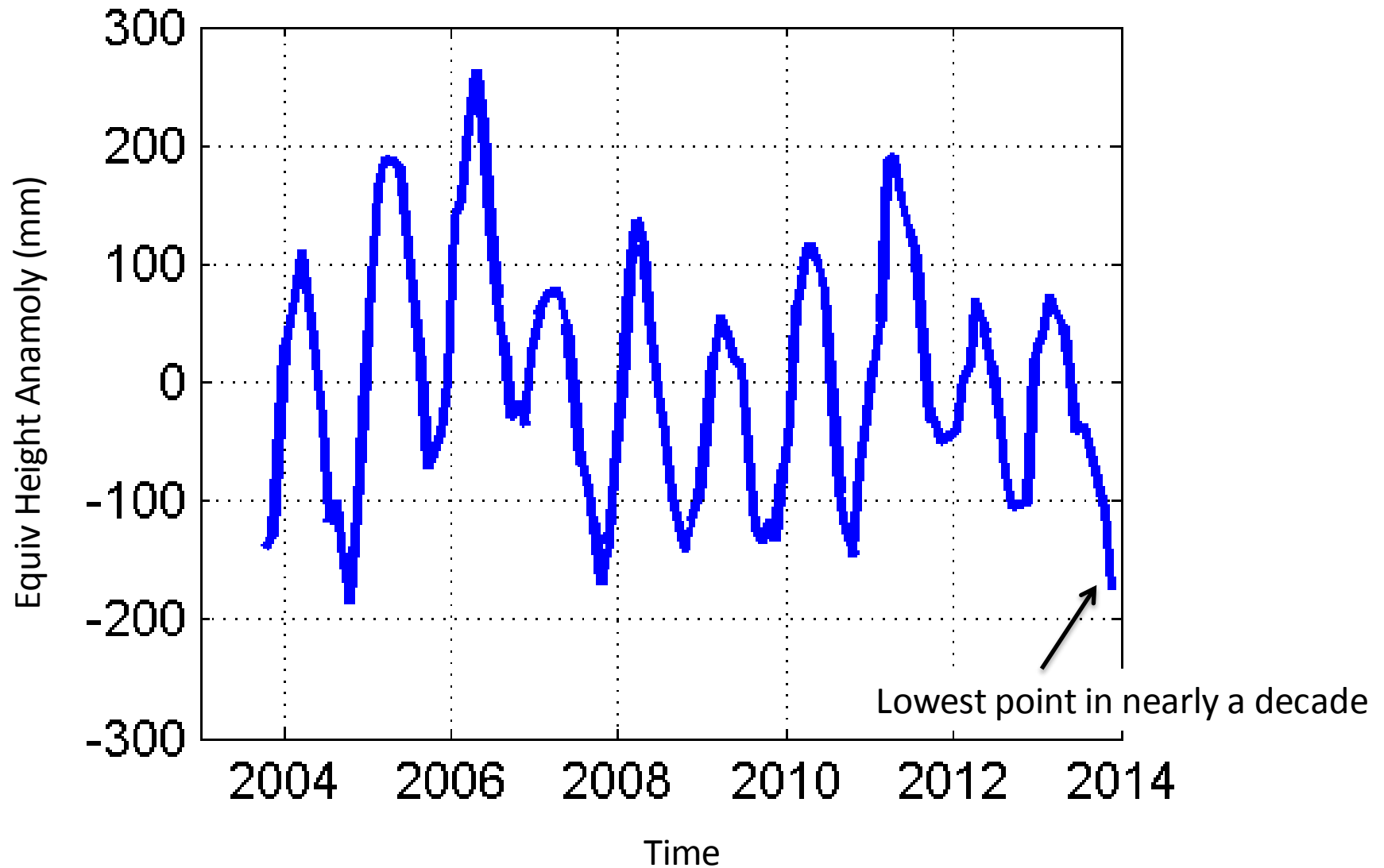


NASA Gravity Recovery and Climate Experiment (GRACE)

- Launched in 2002 with a nominal 5-year lifetime (still working)
- Follow-on (GRACE-FO) scheduled for 2017
- Measures changes in Earth's gravity field (really, in the distribution of mass)
- On land, these mass/gravity are dominated by changes in total water storage, from which groundwater can be isolated
- Functions like a 'scale in the sky' that can weigh the *monthly* increase or decrease in water storage in a *large* ($>200,000 \text{ km}^2$) region with an accuracy of 1.5 cm



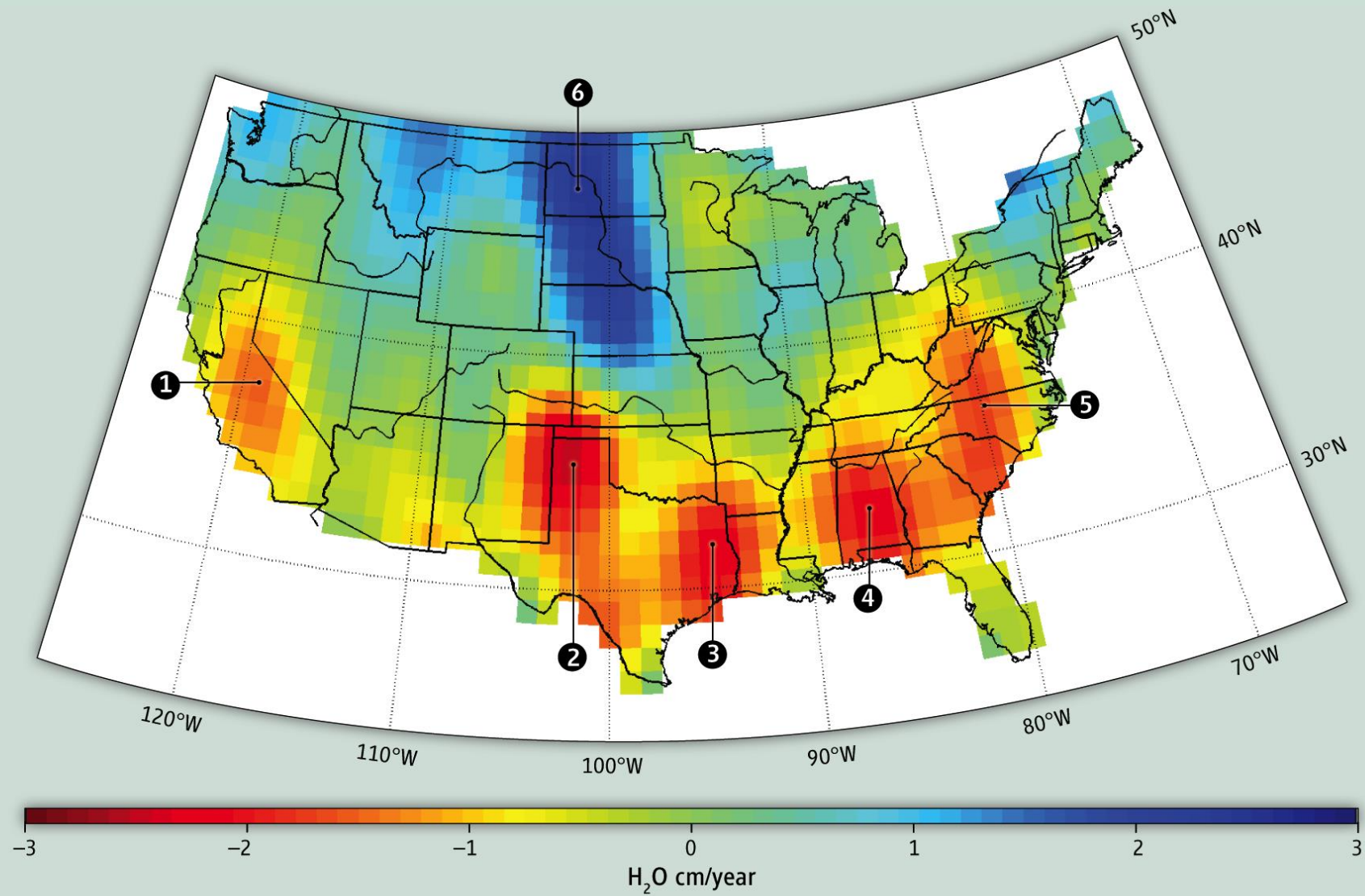
Total Water Storage Changes in the Sacramento-San Joaquin River Basins from GRACE (2003-2013)



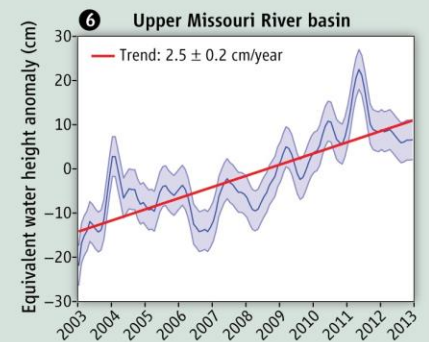
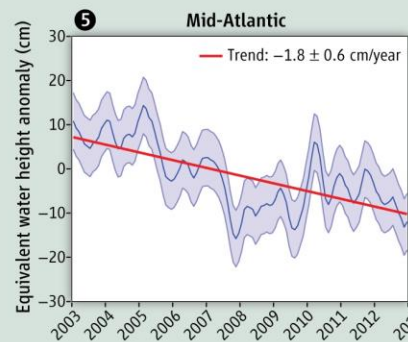
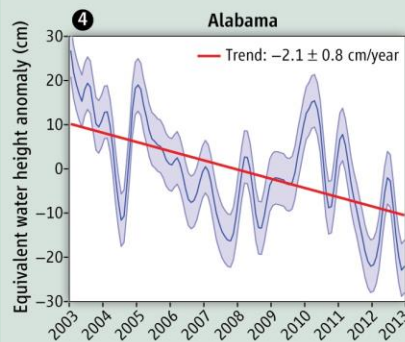
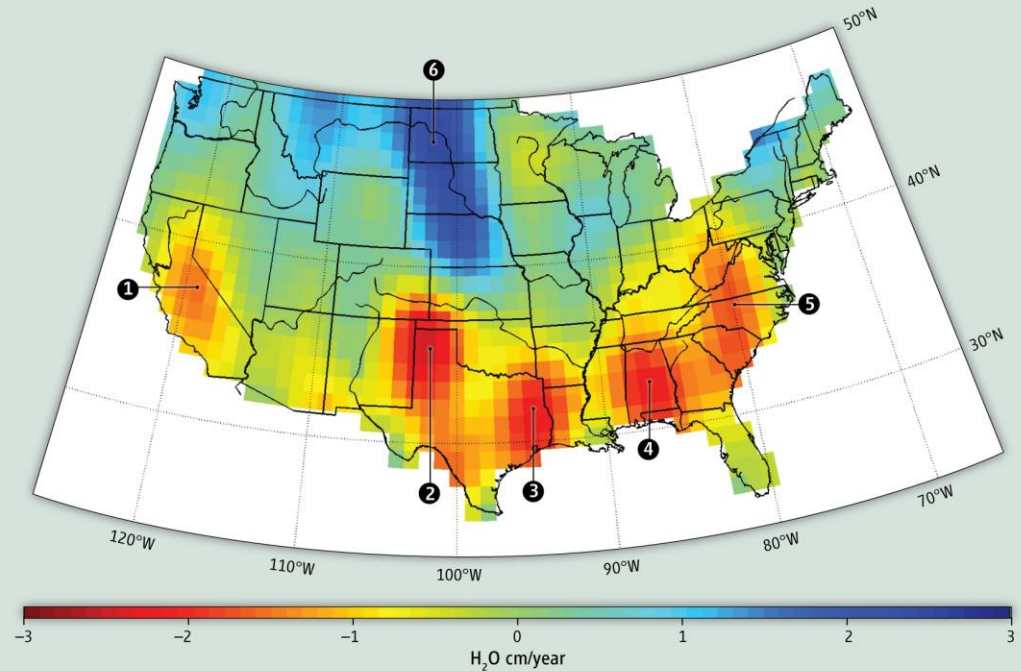
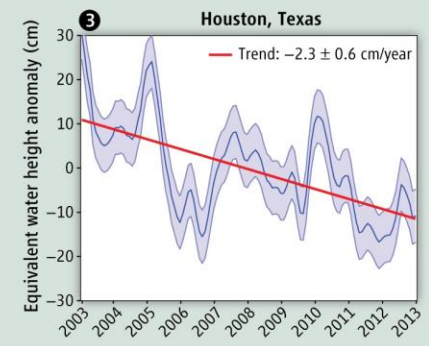
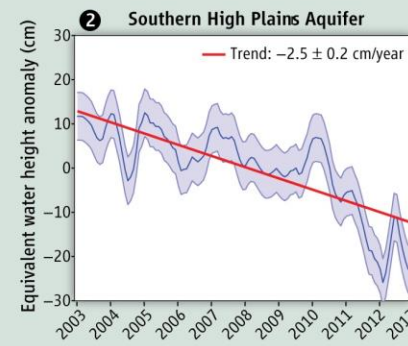
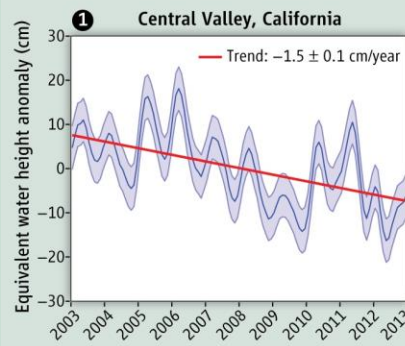
Total Water Storage Changes in the
Sacramento-San Joaquin River Basins from
GRACE (2003-2013)



Trends in Freshwater Storage from GRACE, 2003-2012



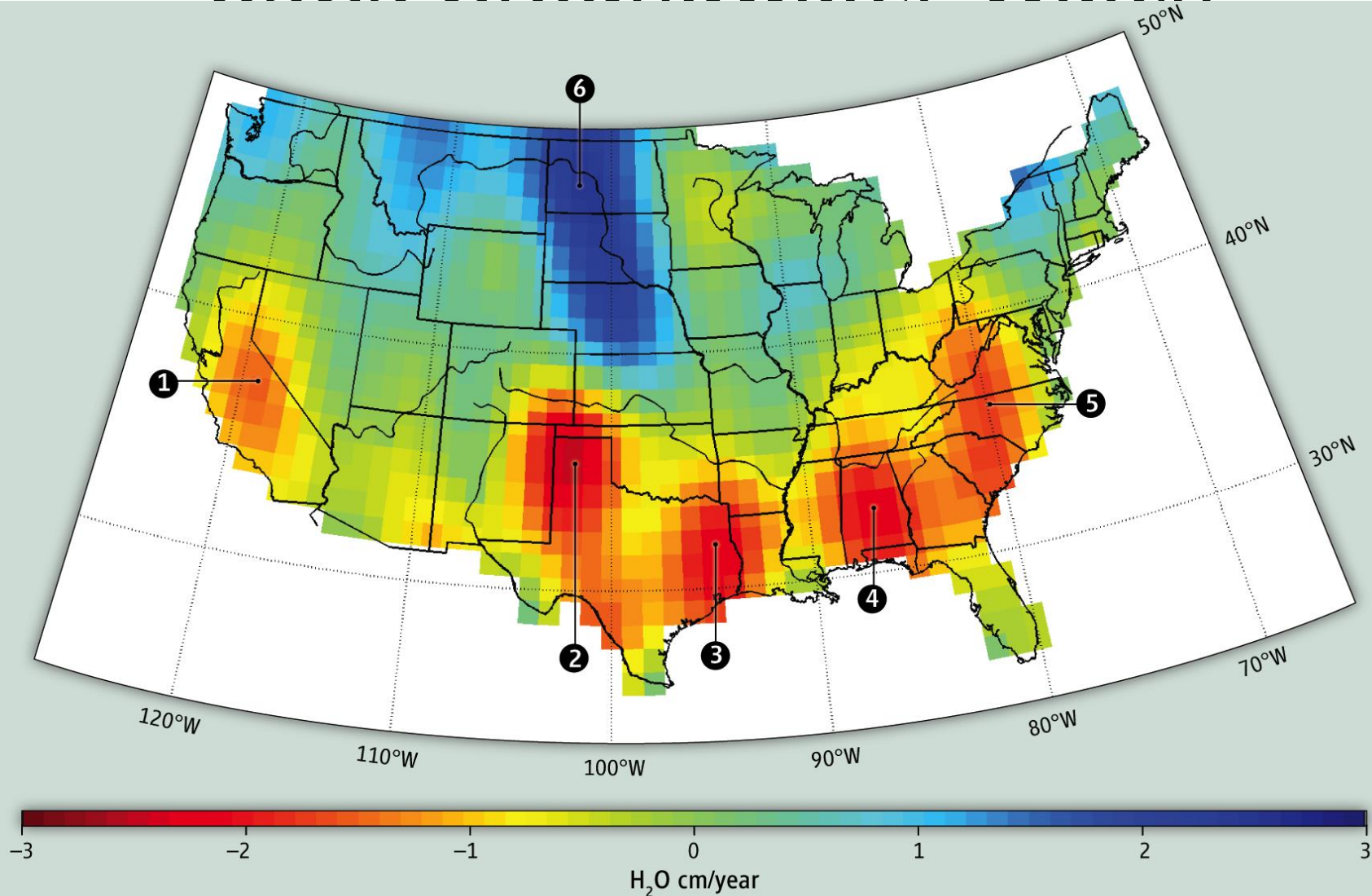
From 'Water in the Balance,' Famiglietti and Rodell, 2013



Trends in Freshwater Storage from GRACE, 2003-2012

*From 'Water in the Balance,'
Famiglietti and Rodell, 2013*

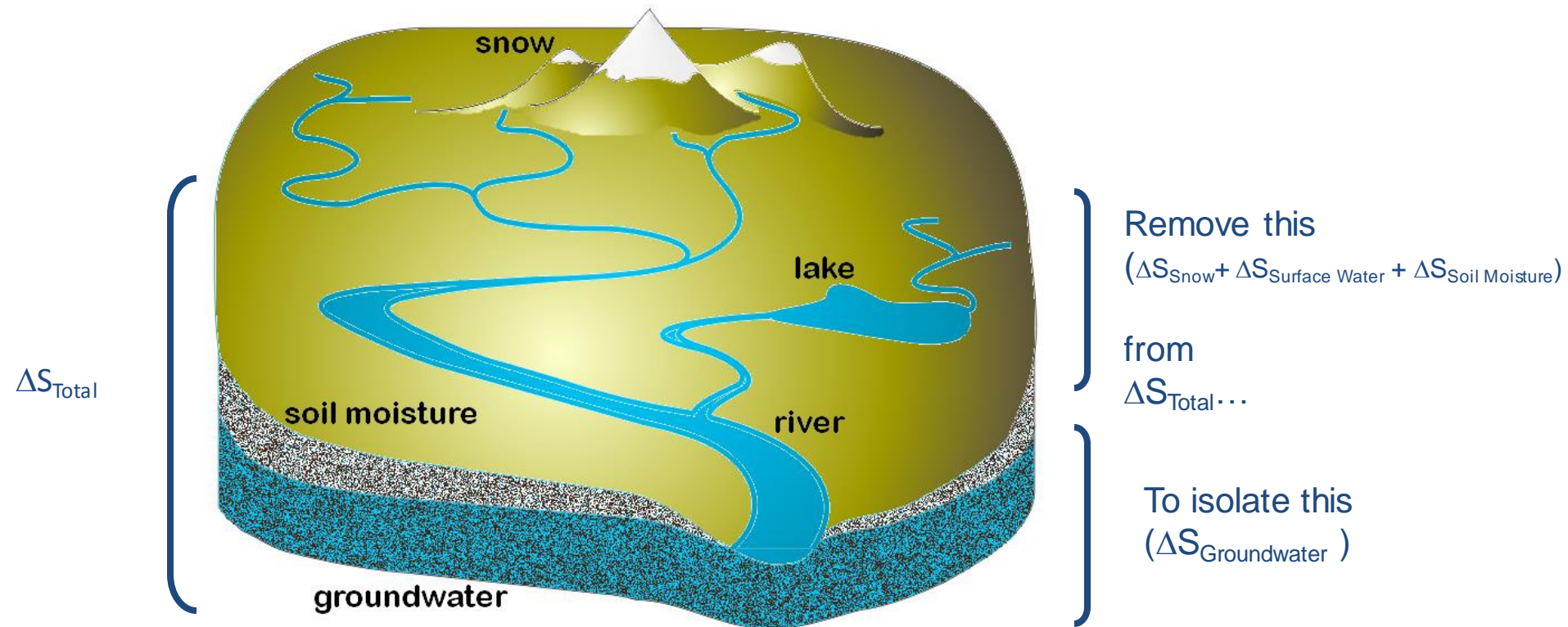
USGS Groundwater Watch



Estimating groundwater storage changes with GRACE

$$\Delta S_{\text{Total}} = \Delta S_{\text{Snow}} + \Delta S_{\text{Surface Water}} + \Delta S_{\text{Soil Moisture}} + \Delta S_{\text{Groundwater}}$$

$$\Delta S_{\text{Groundwater}} = \Delta S_{\text{Total}} - \Delta S_{\text{Snow}} - \Delta S_{\text{Surface Water}} - \Delta S_{\text{Soil Moisture}}$$



Groundwater depletion in California's Central Valley, October, 2003-March, 2009

Sensing Groundwater

Hydrologists have used a pair of ground-sensing satellites, known as GRACE, to measure changes in groundwater storage.

Groundwater Storage

200
150
100

The New York Times Science Times

TUESDAY, MAY 31, 2011

REPRINTED
WITH
PERMISSION

Groundwater Depletion Is Detected From Space

By FELICITY BARRINGER

IRVINE, Calif.

Scientists have been using small

2010

100 miles

GROUNDWATER
LEVEL CHANGE

In feet per year, from 2003-10

+3 -0.4 -1.2 -2.5 -4.1 -6.1 -11 feet

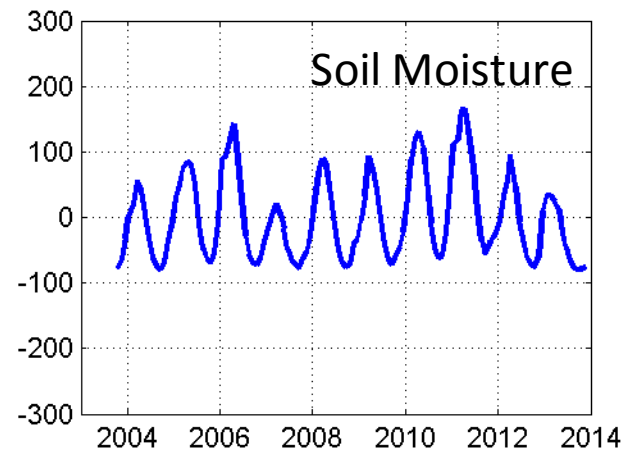
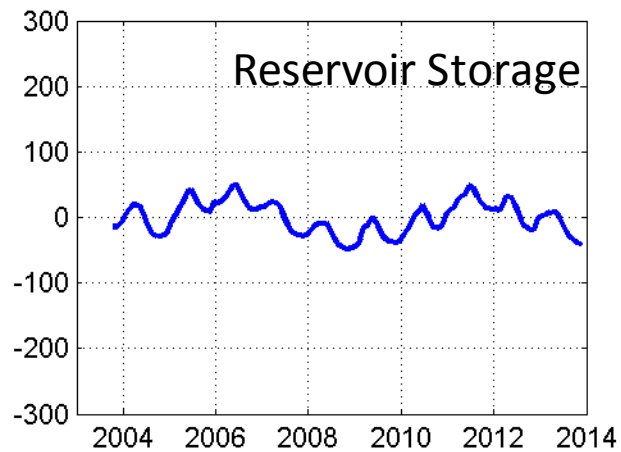
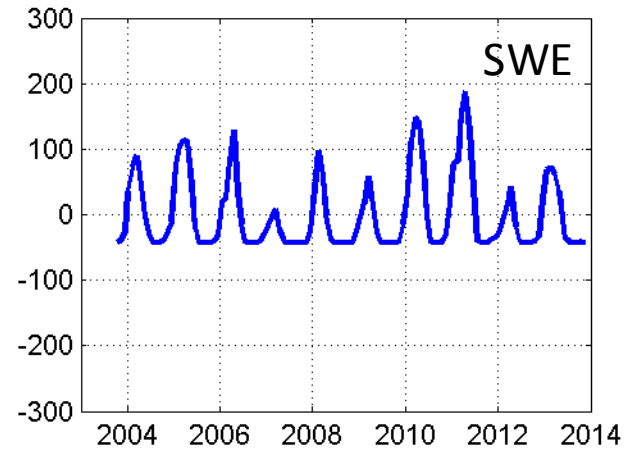
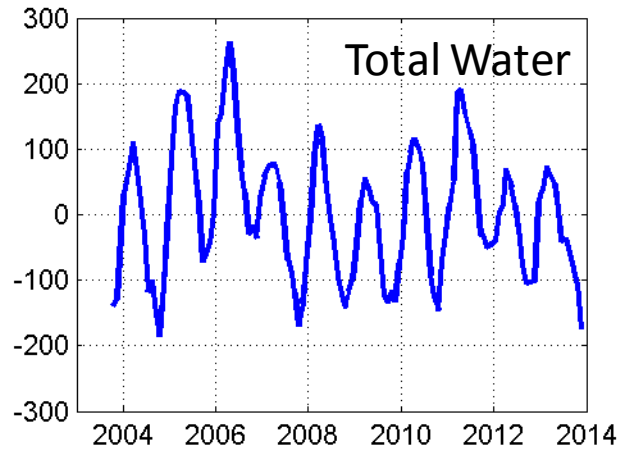
Sources: Jay S. Famiglietti, MinHui Lo and Karli J. Anderson, U.C. Center for Hydrologic Modeling

THE NEW YORK TIMES

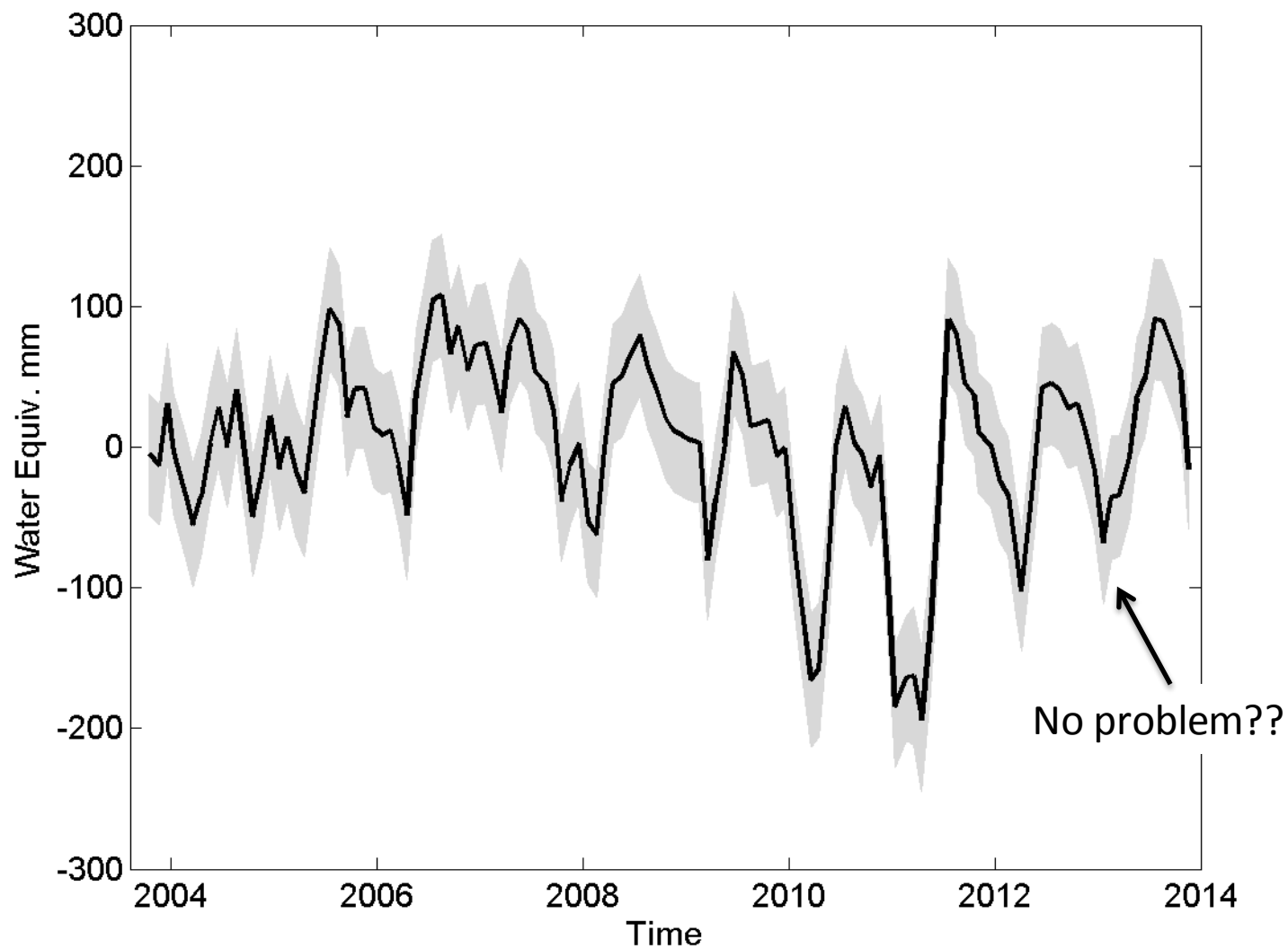
The New York Times, May 31, 2011

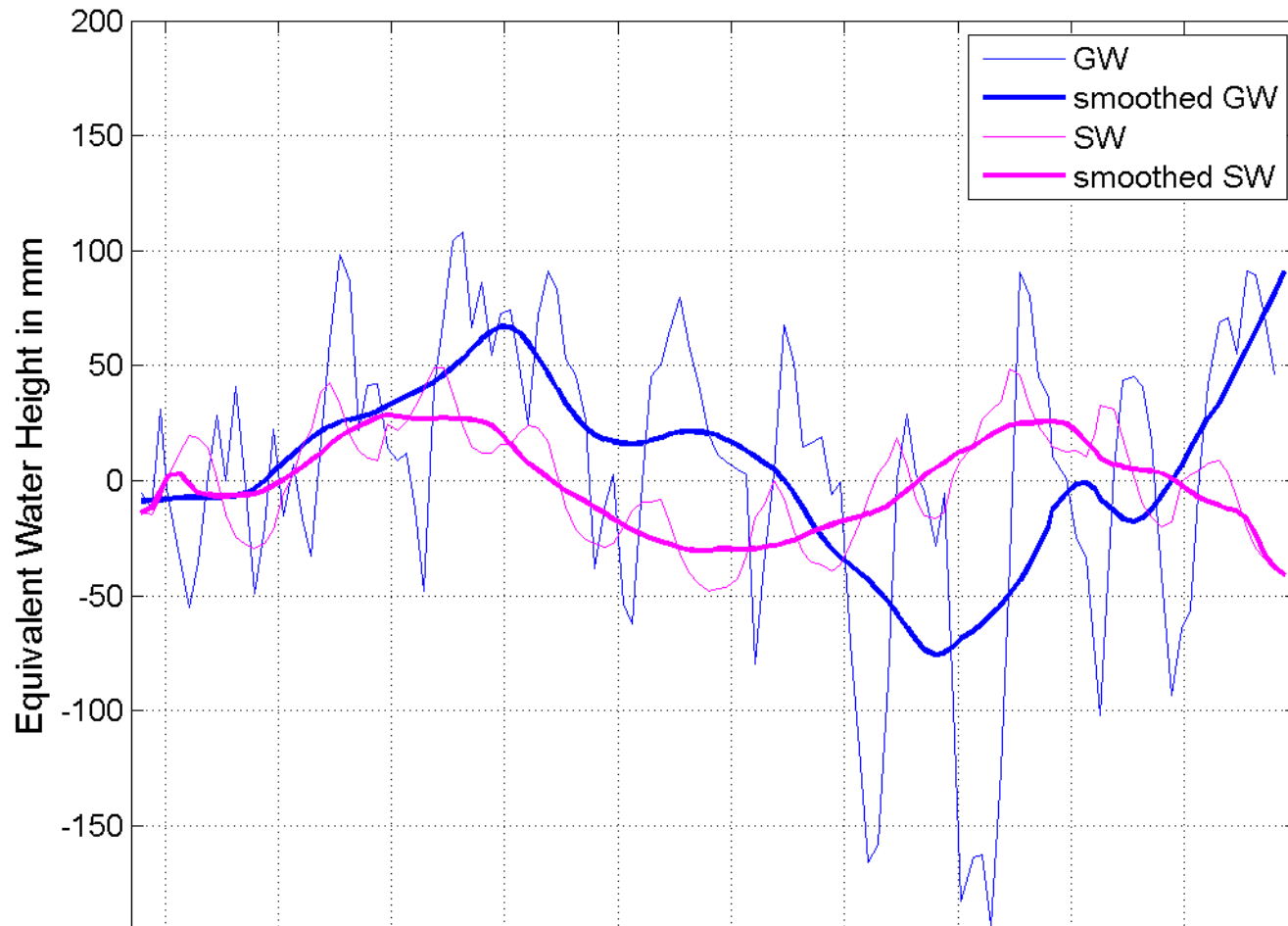
Sacramento-San Joaquin River Basin Water Storage, 2003-2013

Update to Famiglietti et al., 2011



Groundwater depletion in California's Central Valley, 2003 – 2013
Preliminary Update to Famiglietti et al., 2011





- The groundwater response (combined human and natural) to drought lags the surface water response
- It may persist for several years depending upon the length of the drought and water management decisions

Cumulative annual changes in aquifer-system storage, Central Valley, CA, 1962 – 2003

Faunt, 2009

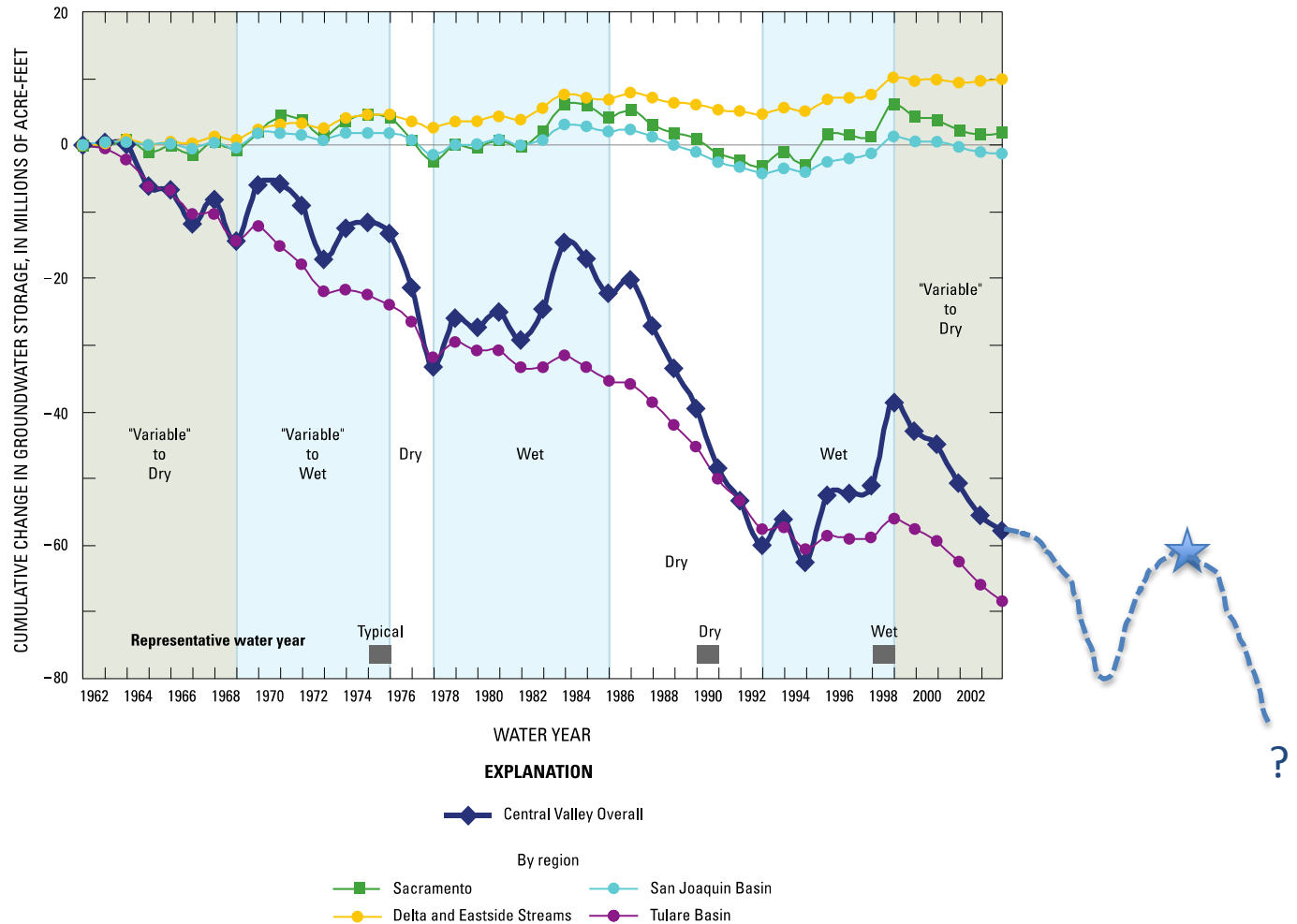
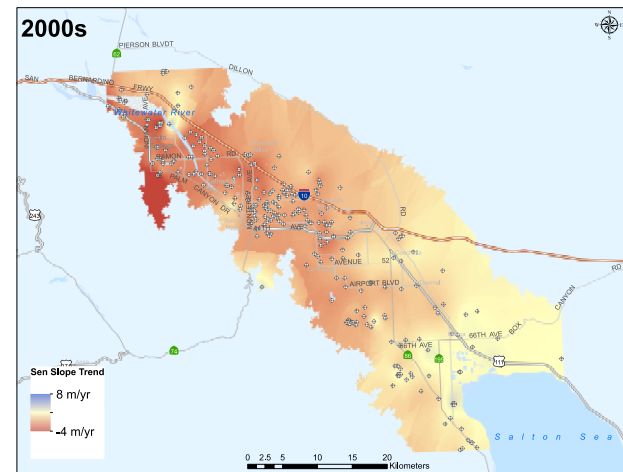
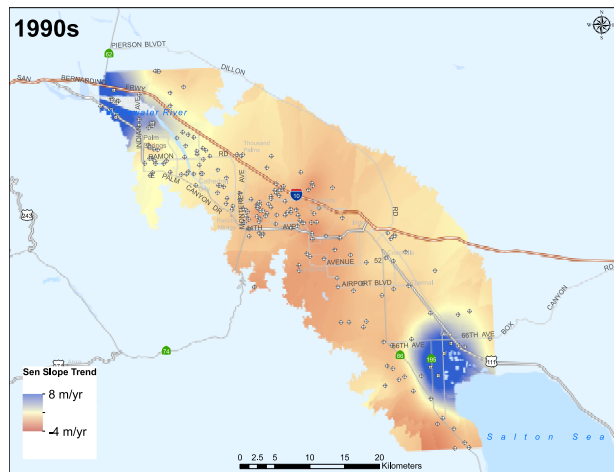
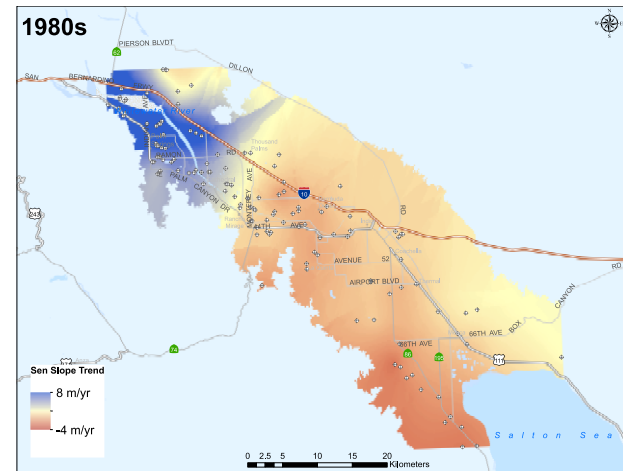
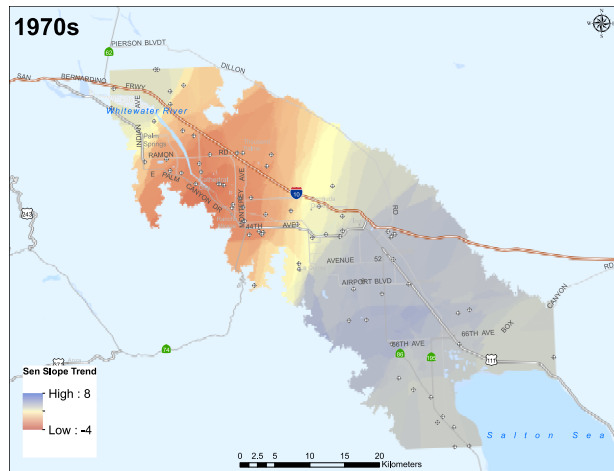


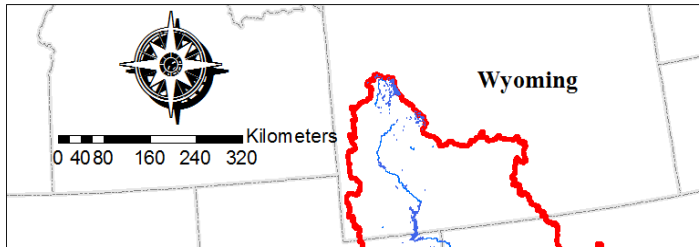
Figure B9. Simulated cumulative annual changes in aquifer-system storage between water years 1962 and 2003 for the Central Valley, California.

Groundwater Depletion in the Coachella Valley

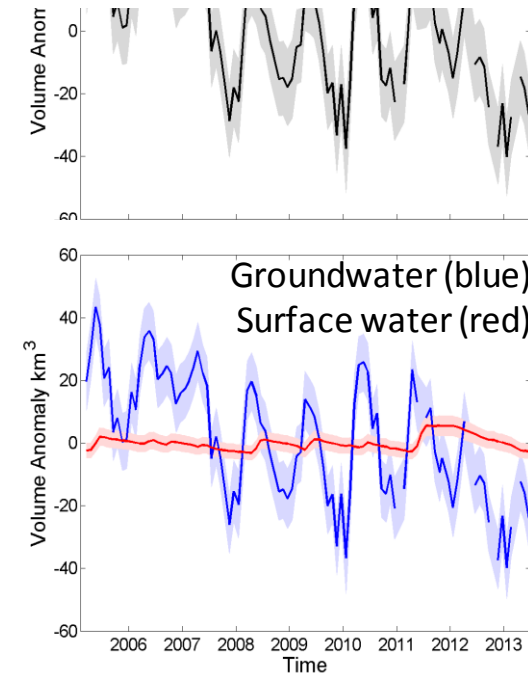
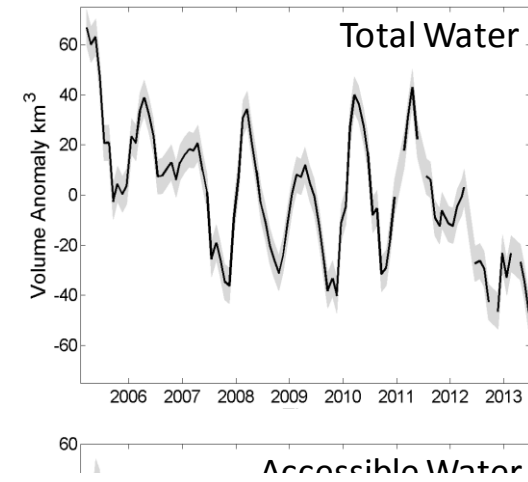
Brian Thomas et al., in preparation



Groundwater use in the Colorado River Basin during drought (2005-2013)

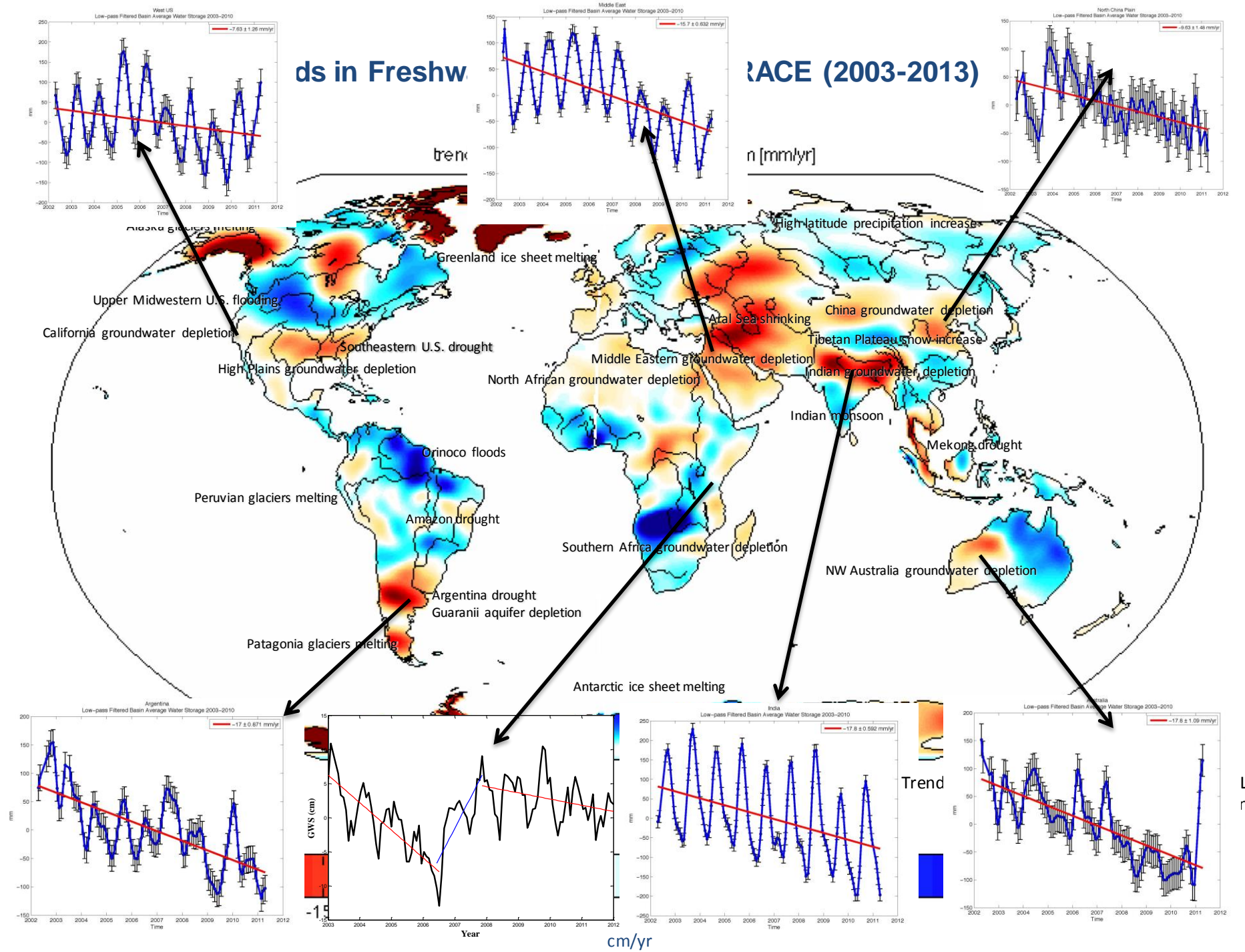


Q: Will declining groundwater reserves in the Colorado River Basin impact the ability to meet future allocations to Basin states?



ds in Freshw

FACE (2003-2013)



Los Angeles Times | OPINION

California's water house of cards

By Jay Famiglietti and Sasha Richey

September 23, 2013



We must raise awareness of the state's critical water issues to the level of everyday understanding.

Once people truly understand that our groundwater is disappearing and not coming back, acceptance of the need for its protection is far more likely.

Questions?



The UCCHM Team at the Groundwater Replenishment System, Fountain Valley, CA